# TECHNOLOGY ROADMAP: WATER USE EFFICIENCY IN CALIFORNIA AGRICULTURE

CONSULTANT REPORT

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# Technology Roadmap

## Water Use Efficiency in California Agriculture

Prepared for the California Energy Commission,

Public Interest Energy Research Program

Agricultural Energy Efficiency Program


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## Executive Summary

This technology roadmap is developed for the California Energy Commission's Public Interest Energy Research (PIER) Agricultural Energy Efficiency program.

This document identifies specific research, development and demonstration (RD&D) project areas for future PIER program funding. The goal is to further increase electricity use efficiency in the process of using water resources in the agricultural industry.

The Energy in Agriculture Program of the California Energy Commission, in cooperation with the California Polytechnic State University (Cal Poly) Irrigation Training and Research Center (ITRC) and industry representatives, has developed the Technology Roadmap for Agricultural Water Use Efficiency. This document identifies critical pathways for the RD&D effort necessary to achieve increased water and energy use efficiency.

A comprehensive study was conducted by ITRC as the foundation for discussion with industry representatives at a November 24, 2003 workshop.

To access the report, please visit:
http://www.itrc.org/reports/cec/energyreq.html

The objective of the workshop was to focus on the key technology areas to achieve increased water energy use in agriculture. Over 40 scientific and marketing representatives with expertise in crop production, water management, water transfers and energy efficiency gathered or were consulted to provide input to the roadmap.

The resulting roadmap sets research priorities for the industry in four broad tracks:

1. Improvements in hardware used to pump, filter and apply water on-farm
2. Reduction in on-farm and system water demands
3. Improvements in the conveyance and delivery of surface water
4. Analyze the impact of current policies on water and energy use.

These tracks have farm-scale, district-scale and regional-scale research needs. In addition, although each of these tracks is distinct there are many instances where implementation of improvements in one area may have implications that overlap into other areas.

The central objective of the research program is to promote effective use of power by 1) reducing the power required to pump and apply a unit of water, and 2) reducing the usage of water having high associated power requirements.

The purpose of the roadmap is to motivate industry stakeholders, research institutions, the academic community, and government agencies to coordinate their research efforts with our high priority research needs.

The future utilization of water resources will require a multi-disciplinary, cross-industry approach. Progress in single isolated technical areas, such as irrigation systems, new materials, or pumping plant improvements, will not be sufficient. Inter-related research projects conducted in a parallel and coordinated manner will be much more powerful. To this end, the roadmap calls for coordination with the California Department of Water Resources, the US Bureau of Reclamation (USBR), the California Bay-Delta Authority, other water agencies and irrigation districts, and farmer organizations. PIER research support will strive to be done in concert with other projects within the cross-industry system.

Acknowledgments:

A broad range of private and public sector groups provided input to this document. In particular the Cal Poly Irrigation Training and Research Center acknowledges the following agencies for providing information and ideas on agricultural energy use in California.

- California Department of Water Resources;
- United States Bureau of Reclamation;
- California Energy Commission;
- Kern County Water Agency;
- Metropolitan Water District of Southern California;
- Arvin-Edison Water Storage District;
- Kern County Water Bank, and
- Semitropic Water Storage District.

Coordination and synthesis of inputs and preparation of this roadmap were carried out by ITRC. ITRC would also like to acknowledge the participants in the workshop for their contributions to developing priorities for future research. Workshop participants are listed in Appendix A.

# Technology Roadmap

**Agricultural Water Use Efficiency**

## I. Introduction

This document provides a roadmap for research aimed at managing the energy demands of irrigated agriculture in California. Two fundamental objectives of this roadmap are to facilitate more effective, efficient energy use by irrigated agriculture and to accomplish this objective as a means of maintaining or enhancing the vigor and profitability of irrigated agriculture.

Almost 75 percent of the approximately 10 million MWH/yr of agricultural pumping energy is located on-farm. On-farm irrigation management and irrigation efficiency are heavily influenced by the quality of water delivery service that irrigation districts provide to farmers. Today, for example, farmers whose water is supplied by irrigation districts can very rarely start and stop their irrigations automatically. Important research objectives include increasing the energy efficiency of on-farm hardware and providing tools to irrigation districts that will enable them to improve their water delivery service to fields.

Although irrigation district pumping and conveyance to irrigation districts account for less electrical energy usage (about 25 percent of the total) than does on-farm irrigation, this conveyance pumping is characterized by fewer, larger Kw pumping plants that are under the control of a small number of persons. Therefore, another research objective is to explore opportunities to implement practices at the district- and project-level that will reduce total annual electricity usage or diminish peak load demand. In some cases, an increase in district-level pumping will be necessary to have a net reduction in pumping by decreasing on-farm pumping.

Four broad tracks have been identified for research to increase the effectiveness of energy use by California agriculture:

### Research to Develop and Install More Efficient Hardware for Delivery and Application of Irrigation Water

This area concentrates on reducing the amount of energy needed to convey and apply a unit of water by determining how to systematically improve the energy efficiency of pumps, motors, filters and application systems. This also includes research into approaches to optimize pumping to take advantage of preferential power rates. While pump scheduling by itself would not reduce power consumption, it would better match power demands with power supplies and would reduce power costs to farmers.

### Research into Techniques to Reduce Gross or Net Crop Water Requirements or Minimize System Losses

This category manages power demands by researching approaches to reduce the volume of water required for crop production. By reducing water demands regardless of the source, these efforts would reduce power requirements in two ways. In the first place, there would be a direct reduction in energy use to the extent that conserved water was derived from sources with high power inputs.

In addition, conservation of water from sources having low power requirements would function as a kind of *in lieu* reduction of power requirements because it permits a greater proportion of irrigation demand to be met by water from sources having low power requirements.

### Research into Strategies to Maximize the Use of Surface Water

The third category focuses on opportunities to improve district facilities and operations to maximize utilization of water having low energy requirements (usually surface water) so that water having high energy requirements (usually groundwater) fills a necessary but supplementary role and is held in reserve when surface water is available. The objective in this area is to efficiently meet irrigation demands using water that has the lowest associated energy requirements.

### Research into the Impact of Current Policies on Water and Energy Use

This category does not fit into the traditional PIER research tracks. However, it is included here because policy decisions on the local, state, and federal level have a large impact on the implementation and effectiveness of various energy efficient technological solutions. The advisory group strongly supported some minimum level of research into this category. This research would not entail policy development but will identify the energy impact of policies affecting water use in the state.

In summary, Track 1 focuses on lowering the per unit power requirement of water conveyance and application, Track 2 focuses on reducing irrigation water diversion and delivery requirements regardless of source, and Track 3 focuses on optimizing sources of water to minimize power requirements. Track 4 is intended to assess policies that advance the potential benefits achievable through the preceding technical tracks.

# II. Research and Development Opportunities and Constraints

## A. Research Opportunities

Table 1 summarizes potential research initiatives grouped by the tracks described above. These potential activities are described later in this section. Many of the more significant ideas are described in detail in Appendix B.

## Table 1. Summary list of potential research activities

| Research Tracks | On-farm Improvements | District or Project Improvements |
|---|---|---|
| **I. Hardware improvements** | | |
| 1. Pumping plant-related | a. Improved pump and motor efficiency and durability<br>b. Improved filter construction and operation<br>c. Investigate inlet conditions<br>d. Investigate column dimensions | a. Improved pump and motor efficiency and durability<br>b. Improved filter construction and operation<br>c. Investigate inlet conditions<br>d. Investigate column dimensions<br>e. Optimize operation of supply and drainage wells |
| 2. On-farm irrigation system-related | a. Improved hand-move sprinkler design<br><br>b. Improved cleaning of drip systems<br>c. Simplified irrigation scheduling<br>d. Research into soft-start/soft-stop hardware | a. Research into soft-start/soft-stop hardware |
| 3. Power-rate-related | a. Power use audits | a. Power use audits, including auditing of delivery strategies |
| **II. Reductions in water demand** | a. Investigate use of Regulated Deficit Irrigation (RDI)<br>b. Research into anti-transpirants | a. Investigate novel approaches to reducing system losses<br>b. Drainage water desalinization. |
| **III. Enhanced utilization of surface water**<br>1. Improved delivery flexibility | | a. Identify solutions for capacity constraints<br><br>b. Develop GIS-based scheduling and routing schemes<br>c. Expand real-time turnout data<br>d. Study of Friant-Kern facilities<br>e. Refinement of canal control integration procedures |
| **IV. Assess policy impacts** | a. Analysis of implications of legislative and regulatory decisions on agricultural power consumption<br>b. Develop guidelines for incorporation of power consumption in future legislative and regulatory decision making | a. Analysis of implications of legislative and regulatory decisions on agricultural power consumption<br>b. Develop guidelines for incorporation of power consumption in future legislative and regulatory decision making |

## Track 1: Hardware Improvements (E.G., Pumps, Motors, Filters)

Research opportunities for reducing the power requirements of irrigation hardware arise from systematically identifying improvements in pumps, motors, filters, and conveyance and application hardware to reduce the power required per unit of water applied. As well as identifying the best technology available for new or replacement installations, research is also needed to determine cost-effective approaches to upgrading or retrofitting existing hardware.

### On-farm Component

#### Pump-related research opportunities

- Work with pump manufacturers to determine if there are ways to construct pumps with:
  - Expanded ranges of flow rates pumped at high efficiencies,
  - More durable materials and construction, and
  - Improved bearing design and construction for deep well pumps.

  Simultaneously, examine why some very high efficiency pumps that are used in the wastewater industry are not used in the agricultural market. For each of the above activities, it will be important to determine the marginal costs of improving efficiencies to determine cost-effective improvements.

  Other pump related research possibilities include:

- Examine inlet conditions of pumps to determine typical losses associated with suction screens and whether such screens are really needed on well pumps. This and the next item are small and simple, but might provide a very simple reduction of Kw-Hr without requiring behavior changes.

- Determine typical well column diameters and assess the power and cost implications of increasing diameters.

- Research ways to reduce drawdown in wells. Although this topic has been researched for many years, additional work remains in consolidating information, researching new chemical and mechanical solutions, and providing that information to consumers.

**Irrigation System-related research opportunities**

- Improve hand-move sprinkler design. Currently the Distribution Uniformity (DU) of these systems is considerably lower than drip/micro, yet these irrigation systems represent about 20-25% of all of California's irrigation. Determine the degree to which modifications such as intermediate risers, new sprinkler designs, and new pressure regulator designs, different spacing, optimum sprinkler pressures, and other factors would lower net power requirements.

- Design and evaluate filters with lower pressure requirements for back flushing.

- Develop simplified irrigation scheduling techniques based on ET with radio/SCADA feedback and archiving and scheduling of hours.

- Research techniques to more effectively remove silt from irrigation district water prior to traditional on-farm filtration. The high silt loads in irrigation district water, plus the lack of flexibility in water delivery (addressed later), are the two major reasons that farmers select groundwater for irrigation instead of surface water, when surface water is available.

- Investigate the efficacy of various cleaning programs for drip/micro systems including gas chlorine continuous cleaning versus liquid chlorine cleaning versus various chemical products and technologies.

- Support research on pumps and motors featuring soft start and stop capabilities that minimize the wear on deep wells when irrigation systems are operated with more flexibility, thereby requiring more on/off cycles (see similar note in the next section).

**Power-rate-related research opportunities**

- Develop procedures to perform power use audits (which will not only examine hardware efficiencies, but which will also examine how water is routed, pumped, used, etc.) to assist districts and individual farmers in determining how pumping programs could be modified to take advantage of discounted rates or to reduce Kw-Hr of pumping.

- Support research on pumps and motors featuring soft start and stop capabilities that minimize the wear on these components that result from frequent starting and stopping of pumps when pumping conforms to rate schedules.

An unintended and undesirable consequence of success in reducing the energy required to convey and apply a unit of irrigation water could be that this reduction might encourage an increase in on-farm pumping volumes, an increase that could result in no net reduction in power usage or even an increase in usage.

This result could be particularly pernicious in areas where farmers might determine that lowered costs of applying groundwater would enable them to reduce their demand for district water. Under this scenario, substitution of groundwater for surface water might become increasingly attractive from the farmers' perspective.

However, this substitution would be likely to raise power usage by replacing district water, delivered with little expenditure of power, with groundwater having substantially higher power requirements.

For this reason, it is important to view improvements in on-farm hardware and management from two perspectives: 1) the on-farm perspective where reductions in power usage and cost of applying a unit of water are clear benefits, and 2) the regional perspective where it is critical that on-farm reductions in power usage per unit of water applied aggregate to a regional reduction in power usage.

### Water supplier component

In parallel to research to improve the efficiency of on-farm hardware, improvements in the efficiencies of pumps and motors and other power consuming facilities operated by water suppliers would also reduce the power used to deliver water and to pump drainage. Research opportunities would be likely to include both hardware rehabilitation and replacement and utilization of strategies to maximize pumping from the most efficient pumps while using less efficient units with less frequency.

Reductions in the unit cost of pumping at the district and project level is unlikely to lead to increases in pumping volumes because district and project water supplies are governed by contracts, allocations or other provisions that limit the availability of surface water under given hydrologic conditions. Therefore, at these levels, reductions in power required to convey and deliver a unit of water are likely to translate directly into power conservation.

## Track 2. Research into Techniques to Reduce Delivery or Diversion Requirements

Research on measures to reduce the volumes of water required for diversion and delivery offer another avenue for reduction of power demands.

### Research into reduction in crop ET

Promising areas of research that could lower power usage by reducing the volume of water required for crop production include the following:

- Regulated deficit irrigation (RDI), specifically on alfalfa by reducing or withholding irrigations during August and July or August and September when water use efficiency is relatively low. Research would be likely to focus on the long-term impact of RDI on factors such as stand life and weed control. The research would need to be conducted in several areas including the Sacramento Valley, the San Joaquin Valley and the Imperial Valley. RDI is already well established in production of wine grapes and research is being conducted in its application to almonds and other tree crops, so no further research is recommended for those crops.

- Research into new anti-transpirants such as humic acid.

### Research into lowering diversions by reducing system losses

At the district and project levels, research opportunities lie in improving techniques to increase the proportion of water supply available for delivery to fields by reducing system losses. As with research into RDI, reduction of system losses would not distinguish between conservation of surface water and of district-supplied groundwater.

Regardless of source, improvements in conveyance efficiency increases the quantity of surface water delivered to the field and reduces the energy expended pumping groundwater. This is achieved by both reducing losses of district-supplied groundwater and by reducing the volume of on-farm groundwater pumping required to replace lost surface water.

- Research into improved canal management/control techniques to reduce and/or recover spillage. Although some of these techniques may have additional power requirements, the net power usage associated with conveyance losses should decrease.

- Research into techniques to reduce canal seepage.

<u>Research into drainage water desalinization</u>

High salinity water degrades streams, rivers, and the groundwater. Eventually, the salt must be removed from the system. Desalinization of tile drainage water can provide new sources of fresh water while simultaneously enhancing the environment. New, lower-energy technologies can be researched to desalinate drainage water, which is more dilute than sea water. Or perhaps it will prove more economical and energy-efficient to concentrate the tile drainage water salinity before desalinization.

## Track 3. Research into Strategies to Maximize Use of Surface Water

Of the three research tracks, the third track may be the one with the greatest strategic value and the greatest potential for long-term reduction of power usage. This track focuses on modifying district- and project-level conveyance and distribution infrastructure and operational practices to optimize the value of available surface water to irrigators.

Track 3 is based on the recognition that the greatest opportunities for power reduction lie in reducing on-farm usage. The greatest opportunities for achieving on-farm water are to foster an environment where on-farm requirements can be met by surface water whenever and wherever surface water is available.

Usage of surface water can be increased by increasing its value versus that of groundwater, the alternative source for many irrigators. To some degree the relative value of surface water versus groundwater is a function of cost, a comparison where surface water is usually attractive. However, another important component of value is the flexibility of deliveries from the two sources.

Groundwater pumped from wells controlled by the farmer is frequently much more flexible than district surface water deliveries. This flexibility is important because it enables farmers to operate drip and micro-spray systems, which can increase farm profitability by improving yield, quality and timing of production.

The flexibility of groundwater use enables farmers to utilize low-volume techniques. Frequently farmers find it more convenient and more profitable to turn from surface water to groundwater, a conversion which, when aggregated over a large number of farms, substantially increases power consumption. Therefore, a major research need lies in determining the most cost-effective approaches to increase the responsiveness of surface water deliveries so that farmers can modernize their on-farm practices while retaining surface water as their basic source of supply.

Research into improved system flexibility

- Identify and develop solutions for capacity constraints in water conveyance, storage, distribution and application systems (including state and federal facilities and district facilities) that hinder load-shifting and energy efficiency measures.

- Identify potential applications and the technology needed for district time-of-use water meters (to encourage more load shifting).

- Develop GIS-based routing schemes for irrigation district dispatching of water orders. Have a generic method that is branching—but with coordinates. Develop a procedure for easily inputting constraints, time lags, maximum flow rate, and inflow and outflow schedules. GIS-based routing schemes must interface with irrigation scheduling software that receives orders.

- Study the Friant-Kern Canal, to determine what districts can take advantage of more flexibility, and what is needed to provide this flexibility. In conjunction with this effort, there may be new opportunities for peak flow releases from the Friant Dam.

- Improve techniques to integrate canal control algorithms into a seamless application process at irrigation districts.

Research supporting expanded conjunctive management

Significant potential for controlling long-term power usage lays in development of effective conjunctive water management programs at the district and regional level.

During periods when surface water is abundant, the objectives of research outlined above will be to maximize the on-farm benefits of reliance on surface water regardless of on-farm practices. However, during periods when surface water is insufficient and groundwater pumping is necessary to maintain crop production, groundwater recharged when surface water is available will maintain groundwater levels in periods when surface water is scarce.

- Research to develop a prototype district operation strategy for determining optimal ranges for groundwater elevations and long-term recharge rates from irrigated lands required to maintain these ranges. The objective of this study would be to 1) determine the potential for district-supplied surface water to support groundwater levels, 2) investigate degree to which programs such as tiered-pricing or practices such as drip irrigation reduce recharge from its potential, 3) evaluate the impact of these reductions in recharge on long-term power consumption, and 4) investigate alternative pricing structures or practices (e.g., recharge basins) that would support conjunctive management.

- Research based on farmer interviews and other first-hand sources to determine likely farmer response to a suite of conjunctive management practices. A concern regarding conjunctive management is that district and regional programs to support groundwater levels may have the unintended consequence of supporting "free riders" who disconnect from district deliveries and pump groundwater to supply micro-irrigation systems. These farmers would benefit from water levels supported by regional recharge programs while contributing little recharge of their own. The objective of this research would be to determine mechanisms to prevent conjunctive management programs designed to reduce power demand from encouraging groundwater pumping during times when surface water is available.

## Track 4. Research into the Impact of Current Policies on Water and Energy Use

Water-related policies by state and national governments can have a huge impact on energy consumption and on peak load demand. In general, as government policy has shifted away from more storage and towards water conservation, pumps have provided much of the flexibility that has enabled that shift. Therefore, increased flexibility has often been attained through greater power usage. Because water conservation and power conservation are seldom considered together by policy makers, there is not a systematic process that has been applied to examine the implications on power usage of proposed environmental or water management projects. Examples of the consequences of policies on power usage are noted below:

- Drip/micro and sprinkler irrigation are promoted in water conservation plans to improve on farm efficiency. The shift from surface irrigation to drip/micro and sprinkler irrigation in many areas of the state has increased on-farm pumping.

- Water quality regulations have reduced the amount of tail water and canal spillage that can enter rivers and sloughs. Capturing and reusing that water almost always requires pumping.

- Research water quality benefits or impacts that result from water use efficiency improvements due to new irrigation delivery methods and improved water management practices.

- Environmental policies promote off-stream storage rather than in-stream storage. However, all off-stream storage requires pumps to lift water to the storage site.

- Water transfers typically require more pumping than do regular deliveries.

- Urbanization causes agriculture in some areas to shift to non-irrigation district lands where the only available water is groundwater.

- Many irrigation and water districts measure irrigation water deliveries by periodically measuring the gravitational water flow through an orifice or weir. With the Cal Fed Water Use Efficiency recommendation on appropriate agricultural water measurement, water suppliers may have to install continuous flow measurement devices. Research is needed on affordable continuous measuring systems using gravitational flow.

The preceding examples demonstrate the need to devote research activity to developing a process to assess the consequences of water use and land use policies on power demand and for integrating these impacts into final policy determinations.

### B. Research Constraints

Because of the great diversity in California's irrigated landscape, it is recognized that one-size-fits-all solutions frequently do not apply. Therefore, latitude will be required in design of the research program to identify activities that are either broadly applicable or that respond to particularly acute situations.

Interactions between water use and power use can be complex in their impacts. Therefore it is vital that research activities are carefully scrutinized to anticipate third party impacts and other possible adverse consequences. In many instances, adverse consequences can be corrected when foreseen. Therefore, identification of possible adverse consequences will often result in formulation of measures to minimize these consequences.

## III. Coordinated Research Approach

The long-term well being of California will be served by development and maintenance of a sustainable approach toward power usage by irrigated agriculture. While farmers and districts generally have rational approaches to power use given their current facilities, improved hardware, refined strategies for hardware utilization and better coordination, and prioritization of water and power usage are likely to reduce power demands.

A multi-disciplinary approach is important to effective progress in the research initiatives outlined earlier in this roadmap. This type of program will enable individual activities to be performed by the entities with the appropriate capabilities and will enable the overall program to attain a degree of depth and breadth that could not be achieved though a more narrowly based approach.

As noted throughout this roadmap, coordination of research activities will be important so that research can progress on separate yet interrelated fronts and so that research results can be successfully translated into programs ready for implementation. An additional important research activity will be the monitoring and evaluation of project implementation and operation so that these experiences can be applied to refining on-going and future projects.

Central to the functioning of the research program will be an organization that will serve as a program manager. This entity will help to establish research priorities, identify funds and match these funds with entities competent to carry out the research.

In addition, the program manager will be central to guiding research through the series of stages identified below and illustrated in Figure 1.

- Conceptual research,
- Production,
- Implementation, and
- Feedback and refinement

The program manager would be involved in framing conceptual research ideas and in reviewing research results. In instances where prototype results are promising, the program manager may also be active in identifying how to transform research or prototype results into production-level hardware or software. Implementation and installation of production level tools generated from research would probably require little input from the program manager, but the manager would be likely to be involved in the monitoring and evaluation of field installations to provide feedback to the research process.

**Figure 1. Schematic showing the role of the Program Manager**

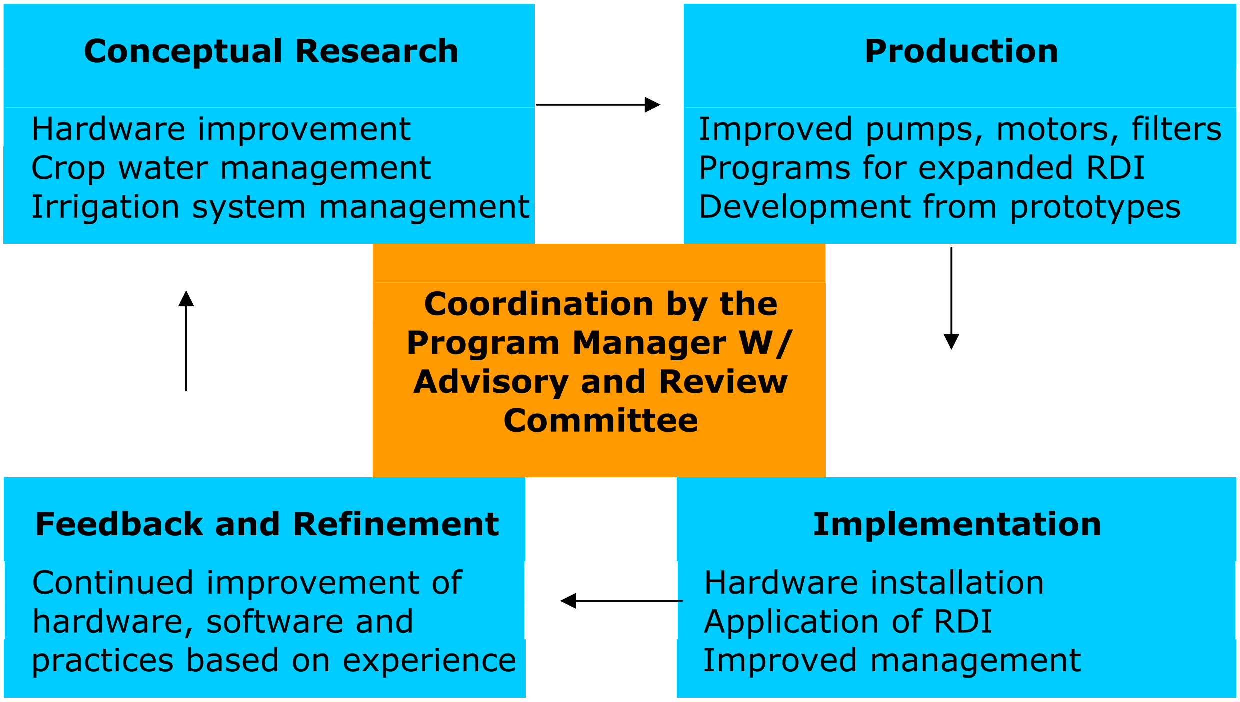


Figure 2 illustrates constraints or considerations that will come into play at different stages in the cycle of research and implementation.

**Figure 2. Key considerations at various stages of the research and implementation process**

| **Conceptual Research** | **Production** | **Implementation** | **Feedback and Refinement** |
|---|---|---|---|
| *Cost of research*<br>*Potential for benefit*<br>*Interactions* | *Practicality*<br>*Unit cost of production* | *Benefit/cost*<br>*Functionality*<br>*Performance* | *Performance*<br>*Price/value*<br>*Interactions* |

At this time, it appears that the following types of organizations are likely to be involved in the research program:

- Universities and research institutions
- Hardware manufacturers
- Developers of water control software
- Irrigation districts
- Electric utilities
- State, Local and Federal agencies

The program manager will coordinate activities among entities participating in research, development and implementation to formulate a development pipeline for conceptual research ideas. The development pipeline will be used to expedite the implementation of successful research programs and to minimize the likelihood of successful research being stranded due to the isolated circumstances of its evolution. The program manager will also seek to avoid duplication of work that is already funded by other sources.

Because the development horizon for research initiatives varies, important research activities would be categorized both by their priority (potential significance) and by the projected time for their development (near term, medium term, long term). The objective of this screening would be to direct funding toward projects having high or medium potential significance and with a range of development horizons. Thus, medium potential projects with short development schedules could be combined with higher potential projects requiring greater time to assemble a program that generated near-term results while supporting more ambitious long-term objectives.

# Appendix A
## Participants in November 24, 2003 Workshop

| | |
|---|---|
| Mr. Ricado Amón | California Energy Commission |
| Ms. Lucille Billingsley | U.S. Bureau of Reclamation |
| Mr. Dale Brogan | Delano-Earlimart Irrigation District |
| Dr. Charles Burt | Cal Poly ITRC |
| Mr. Pete Canessa | Center for Irrigation Technology |
| Mr. Larry Dale | Lawrence Berkeley National Lab |
| Mr. Mike Day | Provost and Prichard Engineering Group |
| Mr. Hicham ElTal | Merced Irrigation District |
| Mr. Russ Freeman | Westlands Water District |
| Mr. Andy Geyer | Alsco-Geyer Irrigation |
| Mr. Lance Goldsmith | Eurodrip |
| Dr. Blaine Hanson | UC Extension, UC Davis |
| Mr. Dan Howes | Cal Poly ITRC |
| Mr. Rick Iger | Kern County Water Agency |
| Mr. Pramod Kulkarni | California Energy Commission |
| Mr. Steve Lewis | Arvin-Edison Water Storage District |
| Mr. Joe Lima | Modesto Irrigation District |
| Mr. Dirk Marks | MWD of Southern California |
| Mr. Tom Martin | Durham Pump Co. |
| Mr. Jonas Minton | California Department of Water Resources |
| Mr. Stuart Robertson | Robertson-Bryan, Inc. |
| Dr. Larry Schwankl | UC Extension, UC Davis |
| Mr. Harry Starkey | Berrenda Mesa Water Storage District |
| Mr. John Sugar | California Energy Commission |
| Mr. Van Tenney | Glenn-Colusa Irrigation District |
| Mr. David Todd | California Department of Water Resources |
| Mr. Marc Van Camp | MBK Engineers (early review) |
| Dr. Dennis Wichelns | Dept of Ag Economics, Fresno State University |
| Mr. Scott Willett | San Diego Co. Water Authority |
| Mr. Gary Wilson | Cal Poly ITRC |
| Mr. Tony Wong | California Energy Commission |

# Appendix B
## Examples of Detailed Research Ideas

### 1. GIS-based Routing of Irrigation District Flows from the Source to the Users

Most irrigation districts require that farmers notify them in advance if they want to start, stop, or change deliveries to turnouts. The average advance notice in California is 24 hours – tremendously better than in other countries, but too long to support the flexibility needed for excellent on-farm management.

In the past seven years, several companies have developed software and hardware to enable irrigation districts to track water orders, integrate these orders with billing programs, and use hand-held data recorders to scan turnout numbers and input delivery information. ITRC, working with USBR, was instrumental in introducing some of that technology to irrigation districts.

What is completely lacking, however, is software that enables water-ordering software (or irrigation district water masters) to quickly identify:

1. If sufficient capacity to make a deliver exists along the whole flow path between the source and the end user, and
2. At what time flow rates must be changed throughout the canal network so that a flow rate change will arrive at a turnout at the correct time.

Instead of receiving instant confirmation of their orders, when they request water, farmers must wait for the "water master" to decide whether or not they can get the water when requested. In order to make his decision, the water master uses "experience" to determine how the flow rate changes should be routed through the system, and whether there is sufficient capacity in all of the canal sections.

GPS-based surveys of canal and turnout locations are becoming commonplace in irrigation districts. Information from those surveys is quickly being put onto GIS-based maps for district use. However, ITRC is unaware of any irrigation district in California that uses the power of GIS to do anything more than make maps in various layers for planning, design, and presentation.

GIS allows the ability to assign attributes to each segment or object. For example, each canal segment can be assigned a maximum flow capacity, as well as the time it takes for a flow rate change to move through the canal. On a real-time basis, one should be able to assign individual turnout flow rates. Because all paths are linked in GIS, one could then utilize GIS program capabilities to compute flow rates in all segments throughout the irrigation network.

To make this capability truly usable for irrigation districts, one must be able to assign names and parcel numbers to turnouts, store future water orders (start, stop, and durations) be able to quickly and easily add and subtract turnouts, plus be able to add new canal sections and their properties. Furthermore, the program must be able to print out summaries of schedules and canal operation for irrigation district employees.

This research activity would develop a prototype GIS-based irrigation order routing software package. The prototype would be made available to (among others) the companies that currently provide water ordering/billing software. Those companies, in turn, would do their own programming and customization of the prototype software.

## 2. Well and Pump R&D

Participants of the November 24, 2003 workshop at the CEC in Sacramento identified pump and well efficiency improvements as one of the top priorities for research. At this time, California does not have a well-equipped, NIST-traceable, independent testing laboratory for pumps. Development of such a laboratory would enable research on the following specific activities:

A. Fill gaps in our knowledge of Variable Frequency Drive (VFD) applications.

   Typical in-field pump efficiencies have been documented by ITRC for irrigation districts at 57% (based on 1,028 measurements in 2001-2003) and by CIT at 51% for farm irrigation pumps (based on 2,893 measurements in 2001-2003). Efficiencies should ideally be in the 75% range, so this difference appears to represent a huge energy waste.

   Variable frequency drive (VFD) controllers, which use electric motors that change their speed depending upon the requirement (in contrast to regular motors that only run at a single speed such as 1800 RPM) are becoming popular because of control advantages (such as being able to have less flow without excessively high pressures) and associated energy savings.

To maximize electricity efficiency and to properly use VFDs with their inherent control advantages, there is a need to better understand two key characteristics of VFDs:

1. The characteristics (efficiency and torque) of standard electric pump motors, when they are converted to VFD units using special controllers. The understanding of pump efficiency is good, but we are simply guessing about the motor efficiencies at the moment. Commercial pump testing facilities have not yet developed methods to properly determine energy input/output characteristics on VFD controlled motors, due to the unusual electronic characteristics.

2. The procedures to define critical resonance of VFD pump systems. That is, at certain RPM's, pumps can begin to vibrate and can cause serious equipment or personal damage.

This project will do the following:

1. Research procedures to properly evaluate electricity input/output on VFD controlled motors attached to pumps. This may involve special filters, requirements of 18-pulse vs. 6-pulse controllers, and other options.
2. Develop a state-of-the-art test bench for motor/pump VFD combinations up to 100 HP, using new electronic technology to measure flow, input HP, Power Factor, Resonance, Motor HP, motor torque, and pressure.
3. Using commercial vibration analysis equipment, define procedures to test pump assemblies for critical resonance before they are installed in the field.
4. Identify at least 30 pumps in the field that farmers or irrigation districts are considering converting to VFD applications. Test each application for vibration characteristics, to determine how serious the problem of vibration can be.
5. Use five "typical" pump/motor assemblies and document the special characteristics of pumps and motors with a VFD controller. This will be used to develop guidelines on procedures to better estimate efficiencies of proposed VFD conversions.

6. Publicize the information in various publications and the ITRC website, as linked to the CEC website.

B. Determine the hydraulics and necessity of inlet screens on well pumps.

Inlet screens are a standard component on well pumps. However, it is not definitively known why they are even used, and what the energy requirement is with and without them. Furthermore, when pumps are removed from wells, the screens generally appear to be greatly blocked by rust. Standard pump tests have no way of detecting the head loss across these screens – any head loss across them will be associated with "inefficiency of the pump". The following information is not known to pump dealers:

1. Compelling reasons to use or to not use inlet screens.
2. Friction loss across new screens.
3. Friction loss across old screens (ones that have been in place for several years).

This research will answer all three of these questions, and then provide specific recommendations to pump dealers as to how/when well pump inlet screens should or should not be used.

The research will combine interviews with well and pump installers across the state, as well as hydraulic testing of the friction loss across new and old screens. Old screens will be obtained from pump dealers across the state.

C. Evaluate the energy implications of existing deep well pump column diameters.

Well column pipe diameters are currently determined by one of the following:
1. The diameter of the pipe thread on the pump bowls.
2. The diameter of the well.
3. The cost of the pipe.

None of these include an assessment of the energy requirements of various diameters of column pipe. In many areas of California, the column lengths are several hundred feet deep. There is no information to determine how many kWh per year are wasted (or if there is a waste) due to small column pipe diameters. If the energy consumption is substantial, changing column pipe diameters represents a relatively simple way to mechanically reduce kWh.

This research will do the following:

1. Obtain data from manufacturers and pump dealers from throughout the state regarding the pump column lengths, diameters, total dynamic heads, and flow rates of pumps that have been sold within the last five years.
2. Compute the percentage of the total dynamic head attributable to column pipe friction. From this, determine the kWh implications for the state.
3. Test the hydraulics of at least ten samples of columns and shafts to see how well the hydraulics match the friction values that are published by pump manufacturers.
4. Perform an economic analysis on the dataset to determine if the present designs are economical and energy efficient.
5. Publicize the results to pump dealers and manufacturers. Make the information available on the ITRC website. Publish results in popular farm journals.

D. <u>Research new pump designs/materials that can produce better efficiencies</u>

ITRC will work with pump manufacturers to identify new ways to construct pumps with a wider range of flow rates, with higher efficiencies, and with more durable materials (less sand wear). The research will attempt to identify new (or unpublicized) pump technologies throughout the world – in a similar manner to what ITRC has done with hydro-acoustic meters. This research will be conducted through literature searches, visits and conversations with manufacturers, and discussion with practitioners who have used various products. The benefits of new advances in computations fluid dynamics (CFD) will be assessed for pump design. The marginal cost of implementing these technologies will be computed.

Research should also be conducted on pump shaft and bearings to reduce friction losses and minimize bearing wear. If shaft diameters could be reduced less flow friction loss would occur for the same column pipe size. Research on the use of large horsepower submersible pumps could also reduce energy use per acre-foot of water pumped.

## 3. Regulated Deficit Irrigation (RDI) Research on Alfalfa and Pasture

Regulated Deficit Irrigation (RDI) is a standard practice on many crops such as processing tomatoes, cotton, and wine grapes. RDI is a tool used on those major crops to obtain the proper balance in growth between the vegetative and reproductive portions of the plant. For example, the total soluble solids of processing tomatoes will be too low unless the tomatoes are stressed for several weeks prior to harvest.

Another entirely different type of crop that RDI can impact is alfalfa, which is a "vegetative" crop. In general terms, there is a relationship between the centimeters of ET and the yield of the crop. It is often understood that if there is a 20 percent reduction in alfalfa ET, the harvested yield will decrease by 20 percent. Standard wisdom decrees, then, that there is no advantage to stressing alfalfa. In particular, it is believed that stressing alfalfa will decrease marketable yield and contribute to a weaker alfalfa stand and more weeds.

That said, a closer look at alfalfa growth shows that during the months of July and August in the Central Valley and in Imperial Valley, the ET is very high but the yield/ET (also referred to as "water use efficiency" by some) is much lower than at other times of the year. Therefore, some researchers have proposed that RDI of alfalfa during July and August can conserve water with a negligible impact on annual yields, in the special case of the Central and Imperial Valleys. The Imperial Irrigation District sponsored a variety of studies on RDI with alfalfa in the early 1990's, and additional work was done in Tulare County and in Arizona. Many of the results were conflicting in nature – possibly due to the experimental design, but also probably due to other factors such as salinity and different alfalfa varieties.

Alfalfa irrigation is important for California energy consumption because during the months of July and August, it represents about 10% of California's irrigated acreage. This probably translates to about 15% of the total irrigation volume during those months. This in turn represents 10-15% of the energy consumption related to irrigation during those months. If alfalfa irrigation could safely be reduced by 50%, this might result in a 5-7% decrease in electrical energy consumption during July and August.

The proposed research would re-open that earlier research on alfalfa RDI by:

A. Examining in detail the prior research, including interviewing earlier researchers and cooperating farmers.
B. Identifying the most probable causes of confusion and uncertainty from previous research results.
C. Summarizing those findings, and making a recommendation for further research, if it is merited.
D. If further research is merited, conducting the research.

## 4. Water/Energy Policy Research

The November 24, 2003 meeting at the CEC offices in Sacramento demonstrated that a high percentage of the participants felt that policy constraints have put serious limitations on water-related power consumption by irrigation districts.  An analytical process was called for that could enlighten policy makers.

The November 24 participants cited several examples of confused or conflicting policy – or, at minimum, policies that impact power consumption but which never considered their power consumption implications.  For example, the agricultural water quality waste waiver for the San Joaquin Valley has not looked at the power implications of its adoption.

Environmental impact statements are a standard requirement for proposed development and policy actions.  Yet one rarely encounters a requirement to conduct an energy analysis for the same actions, to determine how those actions will impact the grid, peak load restrictions, etc.

It was pointed out that future energy needs for agriculture will depend upon the agricultural markets.  A projection of these markets, coupled with the energy impact of individual markets, will provide a projection of energy needs.

Another noteworthy aspect of policies is that they often do not address regional constraints.  Several participants in the November workshop felt very strongly that this was a problem.

Proposed research ideas included the following activities:

A. Document a number of policy decisions by the legislature, Water Resources Control Board, and /or others that have had large energy impacts within California – either by causing increased energy consumption or by impacting peak electrical load demand.
B. Examine the decision-making processes that were used to develop and implement those policies.
C. Produce a finding as to what type (if any) of analytical processes might be followed successfully to enlighten policy makers.

    1. What types of policy-making procedures might be positively influenced by a defined analytical process?

2. What types of policy-making procedures have minimal-to-no chance of being influenced?
3. What types of analytical processes are needed for different types of policy-making procedures?
4. Recommended procedures for institutionalizing the analytical process.
5. An assessment of costs, social, and energy implications of adopting such processes.

5. Other R&D Projects

Some of the more interesting research topics that could yield practical, short-term results might include:

A. Improved performance of standard hand move and side roll sprinklers, for better uniformity and/or lower pressure requirements.
B. Development of ultra-low pressure, pressure-compensating emitters. This type of research would probably be best suited as a competition among existing manufacturers – with an award for the best development in one of two tracks (i.e. tracks for standard emitters and drip tape emitters).
C. Development of better guidelines for drip filters that require minimal pressure for back flushing, and have minimal pressure loss when dirty. Again, this type of research would probably be best suited to include some type of competition among existing manufacturers, in conjunction with a University center that can evaluate stated performance.